Fairness in Collision-Free WLANs

Luis Sanabria-Russo, Jaume Barcelo, Boris Bellalta

Universitat Pompeu Fabra, Barcelona, Spain
{luis.sanabria, jaume.barcelo, boris.bellalta}@upf.edu

***Abstract*—CSMA/ECA is a contention protocol that makes it possible to construct a collision-free schedule by using a deterministic backoff after successful transmissions. In this paper, we further enhance the CSMA/ECA protocol with two properties that allows to fairly accommodate a large number of contenders in a collision-free schedule. The first property, called *hysteresis*, instructs the contenders not to reset their contention window after successful transmissions. Thanks to hysteresis, the protocol sustains a high throughput regardless of the number of contenders. The second property, called *fair-share*, preserves fairness when different nodes use different contention windows. We present simulations results that evidence how these properties account for performance gains that go even further beyond CSMA/CA.**

***Index Terms*—Wireless, MAC, Collision-free, CSMA/ECA.**

I. Introduction

IEEE 802.11 networks use a shared medium to establish communication among nodes. Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is the protocol in charge of coordinating access to the wireless medium in order to avoid simultaneous transmissions by different nodes. If two or more nodes attempt transmission at the same time, a *collision* occurs and the resulting transmission is discarded by the receivers.

Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA) [1] was introduced as an enhancement to CSMA/CA. It is capable of achieving a collision-free state by making very simple changes on the way CSMA/CA behaves: choosing a deterministic backoff after successful transmissions. CSMA/ECA preserves backward compatibility with CSMA/CA (details in [1] and [2]), which is paramount for the coexistence and progressive adoption of the protocol.

The performance evaluation for CSMA/ECA has been presented in [3]. Nevertheless, to the best of our knowledge this is the first work that introduces further enhancements to the protocol, making it possible to allocate a larger number of contenders and achieve greater throughput than CSMA/CA while providing throughput fairness to all users. This is the first step towards the construction of a totally distributed MAC protocol with better performance than the current standard as a consequence of its collision-free operation.

II. Background

Time in WLANs is slotted, and each slot can be classified as empty, successful or collision (accounting for no transmission, successful transmission or collision, respectively).

In CSMA/CA, each contender attempting to transmit a packet chooses a backoff counter $B \in [0, CW(k) - 1]$ randomly, where $k \in [0, \dots, m]$ is the *backoff stage* and $CW(k) = 2^k CW_{\min}$ is the contention window, with $CW_{\min}$ its minimum value. Each passing empty slot decrements B by one; when the backoff counter reaches zero, the contender will attempt transmission. The success of the transmission attempt is only confirmed by the reception of an acknowledgement (ACK) frame from the receiver, otherwise a collision is assumed. If that is the case, each contender involved in the collision doubles its contention window by incrementing its backoff stage and the packet is retransmitted. If the transmission is successful, the sender resets its contention window to the minimum value ($CW(0) = CW_{\min}$).

CSMA/ECA achieves less collisions and outperforms CSMA/CA in most typical scenarios (see [2] and [3]). The only difference with CSMA/CA is that a deterministic backoff $B_{\mathrm{d}} = CW_{\min}/2$ is chosen after each successful transmission. This choice makes it possible for CSMA/ECA to fairly coexist with CSMA/CA [1]. Furthermore, the maximum number of contenders that can be accommodated in a collision-free fashion in CSMA/ECA is equal to the deterministic backoff used after successful transmissions B_{d}.

In a scenario where the number of contenders, N, is not larger than the deterministic backoff B_{d}, eventually all contenders will be able to pick different transmission slots, therefore achieving a collision-free state.

When the system is overcrowded, $N > B_{\mathrm{d}}$, CSMA/ECA suffers a decrease in throughput due to the fact that it is impossible to reach a collision-free operation. This effect can be seen in Figure 1, where $CW_{\min} = 32$ and $B_{\mathrm{d}} = 16$.

The outcome is a mixed system composed of contenders using either deterministic or random backoff counters. Note that the throughput in CSMA/ECA is greater than CSMA/CA's for any number of contenders (Figure 1).

III. A decentralized and fair CSMA/ECA

Because CSMA/ECA is totally distributed, the number of nodes (N) is unknown to all contenders. In the following we introduce a mechanism able to reach collision-free operation without knowledge of N, even for a large number of contenders.

To make it possible to achieve a collision-free state when the system is overcrowded, we instruct nodes not to reset $CW(k)$ after successful transmissions, and pick a deterministic backoff $B_{\mathrm{d}} = CW(k)/2$. This is called *hysteresis* from here on.

Hysteresis produces deterministic backoffs that are larger than $CW_{\min}/2$, thus making it possible to allocate more

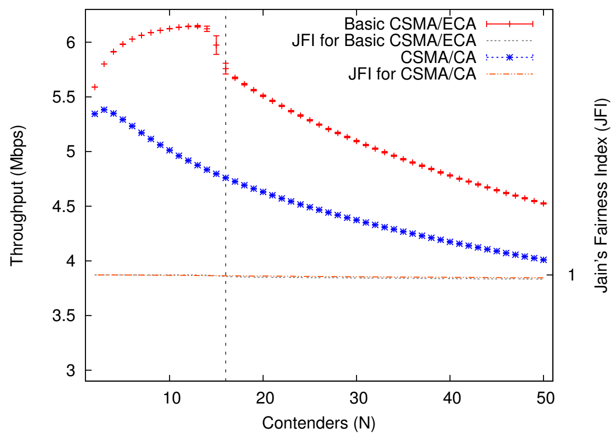

Fig. 1. The throughput is CSMA/ECA decreases when the number of contenderes N exceeds B_{d}, which is the maximum number of contenders that can be allocated in a collision-free fashion.

contenders in a collision-free fashion. Contenders may be in different deterministic backoff stages, which provokes some nodes to access the channel more often than others. This fairness issue, that can be observed in Figure 2, is averted with *fair-share*. The concept of fair-share, was first introduced by Fang et al. in [4].

Fair-share consist in allowing each contender to send 2^k packets at every transmission, making sure that contenders with longer backoff are compensated proportionally.

Figure 2, depicts how CSMA/ECA with hysteresis and fair-share achieves greater throughput than CSMA/ECA with hysteresis only, maintaining a collision-free state while being fair (Jain's Fairness Index [5] (JFI) equal to 1), for any number of contenders.

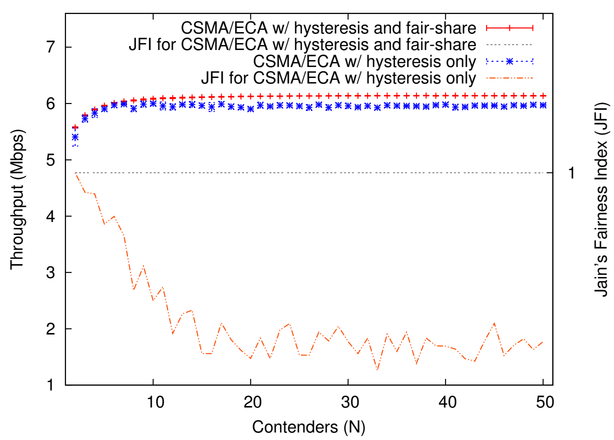

Fig. 2. Throughput and Jain's Fairness Index when implementing hysteresis and fair-share in CSMA/ECA

This work evaluates the performance of CSMA/ECA when implementing the concept in a customized C++ simulator.

IV. Evaluation

Implementation is performed on a customized version of the COST [6] simulator. The system was set to be under saturation (nodes always have packets to transmit) during a period of ten seconds at a maximum throughput of 11Mbps. The number of contenders ranges from 2 to 50 and a hundred simulations are performed for each number of contenders. Further MAC-related parameters as well as the code for the whole CSMA/ECA implementation can be found in [7].

Figure 1 and Figure 2 are results derived from the evaluation platform with 95% confidence intervals. Note that the confidence intervals are so small that can hardly be appreciated in the figure.

V. Future directions

To produce a throughout analysis of CSMA/ECA, more evaluations need to be carried out under non-saturated conditions. Further enhancements include the reset of the backoff stage when the transmission queue is empty and to determine what is its impact on the overall performance of the protocol.

Also, future development will be focused on implementing CSMA/ECA in cheap commodity hardware [8]. Doing so will open the door for evaluation under more realistic scenarios as well as provide insight on different communication aspects, for example those regarding channel errors, delay, synchronization, coexistence with other access protocols and real network traffic.

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